Long-term behavior of induced seismicity in the Val d’ Agri basin (Southern Apennines, Italy).

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The Val d’ Agri (VA) basin in the southern Apennines seismic belt is one of the regions in the central Mediterranean with highest seismogenic potential, testified by a M7+ historical earthquake in 1857. In the past forty years, the Val d’ Agri basin only experienced weak background seismicity (M_{max} 3.2). This background activity coexists with two well-documented cases of anthropogenic seismicity. The first case is related to the operation of the largest onshore oilfield in Europe, hosted in a high productive reservoir formed by naturally fractured, low-porosity carbonates. Hydrocarbons are currently extracted through 22 wells from 1.8 to 3.5 km depth below sea level. Extraction started in the mid-1990 and present-day oil production rates 80,000–90,000 barrel (bbl)/d with 2.6 x 10^5 m^3/d of associated gas. Due to a low primary porosity of the reservoir rocks, production is controlled by fracture systems at various scales. Since 2006, co-produced saltwater is re-injected at 3 km depth in the Costa Molina 2 (CM2) well located at a marginal portion of the carbonate reservoir, with injection rate and well-head pressure reaching maximum values of 2800–3000 m3/d and 13–14 MPa, respectively, inducing well-documented microseismicity (M_{max}2). The wastewater injection, which started on June 1st 2006, has continued since then without major interruptions. The second case of antropogenic induced seismicity includes M3+ swarms that have been associated to the medium-sized Pertusillo water reservoir (PWR) characterized by seasonal water-level oscillation as high as 40 m, corresponding to storage changes of about 110 million m^3. In this work, we show a comprehensive analysis of the spatiotemporal seismicity distribution in the Val d’ Agri area, by using data collected during the 2001-2014 by integrating three different permanent and temporary dense networks. Due to the presence of continuously recording permanent stations run by INGV, we also used cross-correlation (CC) matched filter technique to look for undetected earthquakes with the aim to decrease the completeness magnitude of the available seismicity catalogue. Seismicity data have been used to compute high-precision seismicity locations by integrating cross-correlation and double-difference methods and to reconstruct the detailed three-dimensional Vp and Vp/Vs tomography structure of the area. The properties of the carbonate reservoir (rock fracturing, pore fluid pressure) and inherited faults control the occurrence and spatiotemporal distribution of seismicity. For the CM2 wasterwater injection-linked seismicity, the comprehensive picture obtained by integrating reservoir-scale tomography, high-precision earthquake locations, and geophysical and injection data suggests that the driving mechanism is the channeling of pore pressure perturbations through a high permeable fault damage zone within the reservoir. Analogously, the combined interpretation of the spatiotemporal seismicity distribution with the velocity structure the PWR induced seismicity, suggests that the observed seismicity migration can be caused by poroelastic deformation of the fractured water-bearing carbonates in response to the seasonal loading of the PWR.

Keywords: induced seismicity , fault zone structure, velocity model , high-precision earthquake locations

